ANALYSIS OF IMPURITY CONCENTRATIONS IN a-Si FILMS USING A LOW ENERGY NUCLEAR REACTION

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Introduction

It has been recognized that the use of ion beams is very useful for material analysis. Especially, the Rutherford backscattering of energetic ions is a well established technique for determining composition profiles and thickness of thin films. However, using this technique, some difficulties arise in detecting elements with low atomic numbers and in discerning elements with similar atomic masses, which sometimes require special film-substrate arrangements and high energy accelerators. On the other hand, the nuclear reaction method is useful for detecting light elements in matters. It can be applied to bulk materials and a low energy accelerator will suffice for detecting some elements.

In this report, fluorine concentrations in fluorinated amorphous silicon (a-Si(F)) is determined using the $^{19}F(p,\alpha\gamma)^{16}O$ reaction, and it is demonstrated the low energy nuclear reaction method is useful for film analysis as well as the high energy backscattering technique.

Experimental method

The use of $^{19}F(p,\alpha\gamma)^{16}O$ reaction has been shown to be sensitive method for the detection of fluorine.[1,2] This reaction exhibits many resonances which result in the emission of 6.13, 6.7 and 7.1MeV γ-rays. The resonance of prime concern for our studies is the one at a proton energy of 340keV, which has a cross section of 160mb and a width of 2.4keV. Protons were accelerated by a 400keV Van de Graaff accelerator. The proton beam was collimated to a diameter of 4mm and beam currents were about 50nA. a-Si(F) samples[3] were placed in a target chamber at an angle of 45° with respect to the proton beam. γ-rays were collected using a 3"x4" NaI(Tl) detector placed 21cm away from the target at a laboratory angle of 90°.

Results

Figure 1 shows spectra of γ-rays produced by the 340keV resonance. Although the three lines of γ-ray are discernible in the spectra, the diffrence between the samples which have been confirmed by the backscattering technique to have different fluorine contents in a-Si(F) films. The fluorine concentration can be obtained by comparison with a standard. In our studies the total γ-ray yield was compared with results from the 2.8MeV $^4He^+$ backscattering measurements for the a-Si(F) films on carbon substrates. The results are shown in Fig. 2. The axis of abscissa in the figure is the atomic ratio of F to total atoms in a-Si, which means the effect of the additive rule for the stopping power has been taken into consideration. As can be seen in the figure, within the error, the γ-ray yield is in proportion to the fluorine concentration in a-Si(F) films. If we determine the fluorine concentration only by comparing intensities of γ-rays between the sample and a standard, the stopping power of the samples may be assumed to be a constant value corresponding to that of the host materials. But this assumption will lead an error of only a few percent because light elements such as F do not affect significantly the stopping power of the samples.

It has been demonstrated that the determination of F concentration using the nuclear reaction method at low energy is useful when the energy of an accelerator is limited .

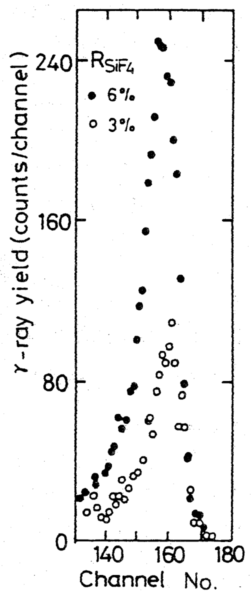

Fig. 1. γ-ray spectra from a-Si(F)

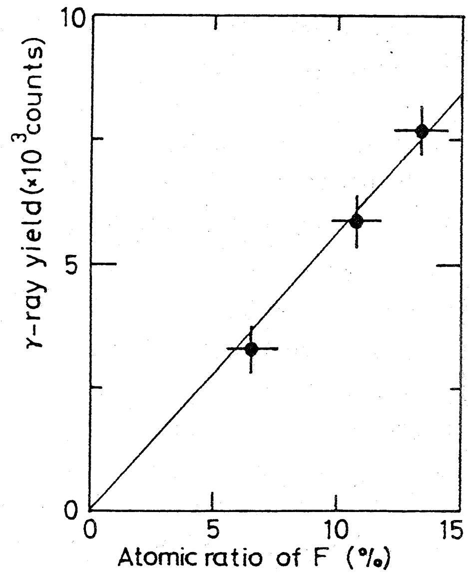

Fig. 2. γ-ray yield vs. atomic ratio of F to total atoms in a-Si(F)

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